DOWNSTREAM PASSAGE AND BEHAVIORAL RESPONSE

OF JUVENILE SALMON AND STEELHEAD

AT HYDROELECTRIC DAMS IN THE COLUMBIA RIVER SYSTEM.

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Introduction

From 1905 to 1975, an extensive series of hydroelectric dams were constructed on the mainstem Columbia and Snake rivers (Figure 1). These dams converted nearly 1500 km of riverine habitat to a series of reservoirs, created obstacles to upstream passage of adult salmon and steelhead (*Oncorhynchu*s spp.), and resulted in high loss rates for juvenile salmonids migrating downstream through turbines. Mitigation of hydro project effects on juvenile salmonids has focused mainly on construction of mechanical bypass systems (in-turbine screens) and increasing the discharge of water over spillways (surface spill). However, not all hydroelectric projects in the Columbia River system currently have bypass screens. Further, application of spill strategies to pass juvenile fish is limited by water quality standards that specify spill levels must not cause lethal gas supersaturation values. Current management agency goals call for 80% fish passage through non-turbine routes. Because these goals are not met at most hydro projects, even those with intake screens in place, some spill is required. These tradeoffs have resulted in focused development and operation of additional mechanical bypass systems. The objective of this paper is to summarize recent research directed at providing a safe route for smolts past hydroelectric projects, including studies related to development of surface collectors and other bypass systems.

Figure 1. Columbia and Snake rivers with hydroelectric projects

Downstream Passage Routes

Juvenile salmon have several passage options when they arrive in the forebay upstream of a hydroelectric project (Figure 2). They can follow the bulk flow through the powerhouse where they may be diverted by intake screens or pass directly through the turbine. They may also pass over the spillway if the hydraulic capacity of the project is exceeded or if any turbine units are shut down. Other routes, including ice and trash sluiceways, are sometimes used to attract and divert fish from the turbine intakes. Surface flow bypass and collection systems are also under development throughout the Columbia River basin.

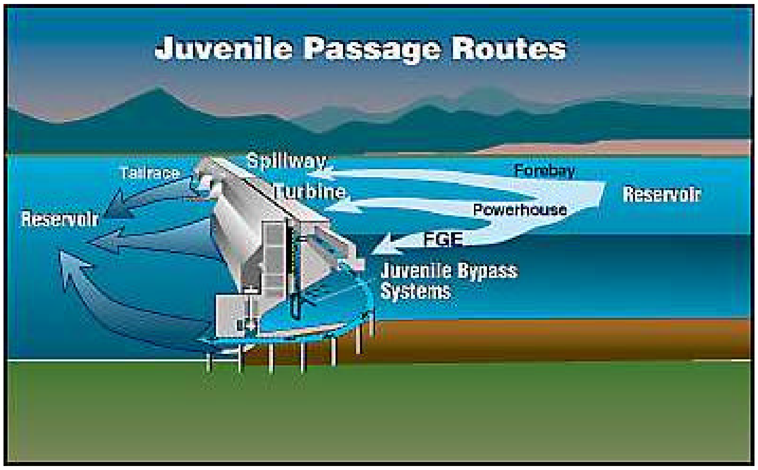

Figure 2: Cross-sectional diagram of juvenile passage routes at a dam

Forebay diversion structures may successfully move fish to a particular passage route. At Lower Granite Dam on the Snake River, a behavioral guidance structure effectively decreased the number of fish entering turbine intakes (Johnson et al 1999). Determining how fish respond to structures is a key unknown for bypass studies. For example, they might respond to structure as a boundary and maintain a certain minimum distance from it, migrate along a particular velocity gradient, or respond to turbulent flow patterns. Knowing this behavior would be helpful in design of both the effective size and placement of fish bypass structures.

We believe that smolts respond to environmental stimuli over a range of measurement scales that collectively influence the passage route a smolt takes past a dam. Collecting data across the full range of response and measurement scales, and integrating this information within experimental protocols, would provide a greater understanding of the biological basis for smolt passage at hydroelectric facilities. (Table 1)

Recent hydroacoustic and radio telemetry studies have shown that smolt distributions immediately upstream of hydroelectric projects are affected across both channel (10^2 – 10^4 m and local (10^1 to 10^2 m) measurement scales (reviewed in Dauble et al. 1999). For example, smolts appear to follow the bulk flow in the thalweg. Site-specific differences in forebay bathymetry influence bulk flow and affect smolts distribution, i.e., both depth and channel dimensions may allow smolts to disperse vertically and horizontally. The amount of river flow and turbine operations also influence fish approach patterns and affect the relative numbers of smolts available for each passage route (Johnson et al. 1999). Projects that are not aligned perpendicular to the flow typically have more complex forebay hydraulics and more variable fish distributions**.**

Table 1. Spatial hierarchy describing conceptual measurement scales for comparing smolt response to its environment (modified from Dauble et al. 1999)

Measurement Scale	Quantitative Dimension	Forebay Zone	Principal Features
Channel	$10^2 – 10^4$ m	Approach	Approach, channel depth and shape, discharge, shoreline features, current pattern
Local	$11^2 – 10^2$ m	Discovery	Forebay bathymetry, structures, velocity, gradients, sound, light
Site	$10^0 – 10^1$ m	Decision	Velocity gradients, Turbulence, other fish, structures, sound, light

Fish Response to Flow

Various studies support the prevailing hypothesis that downstream migrant smolts can detect water velocity and acceleration fields at dams. How fish use this information is a key feature of surface bypass development, yet is largely unknown. Most surface bypass structures have been designed to create flow fields at fine scale (10^0 – 10^1 m) dimensions. Flownets may have a threshold size, below which smolt passage is reduced (Haro et al 1998). Other studies indicated that smolts detect and respond to near field flow characteristics associated with different bypass screen designs (Nessler and Davidson 1995). Potential differences between flow field signals produced from ambient (e.g., from turbine operations) versus those produced from bypass structure flow fields i.e., “the signal-to-noise ratio,” are likely to influence smolt behavior and passage. Ambient light also affects the vertical distribution of juvenile salmonids. Smolt response to turbulence, flownets, sound, and light would be expected to occur at scales $<10^1$ m.

Summary

Several factors influence the downstream passage success of juvenile salmonids at hydroelectric dams in the mainstem Columbia and Snake rivers. The primary physical factors present in the forebay upstream of the dams include river discharge, channel morphology, and hydraulics resulting from project operations. To date, cause-and-effect analysis relative to performance of smolt bypass systems has focused almost entirely on local hydraulics. Other environmental variables , such as sound and light, should also be measured and factored into smolt behavioral response. Future efforts should focus on increasing the opportunity of discovery for downstream passage routes. To do this, additional research is needed to evaluate what conditions, and at what measurement scale, smolts actually respond to.

References

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